

Tests of Mutagenesis and Reproduction in
Male Rats Exposed to 2,450-MHz (CW) Microwaves

(U.S.) Health Effects Research Lab.
Research Triangle Park, NC

26 Dec 79



TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)			MS-80-063
1. REPORT NO. EPA-600/J-80-264	2. JOURNAL ARTICLE	3 PB81-152064	
4. TITLE AND SUBTITLE Tests of Mutagenesis and Reproduction in Male Rats Exposed to 2,450-MHz(CW) Microwaves		5. PERIOD DATE April 1981	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) E. Berman, H.B. Carter, and D. House		8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Experimental Biology Division Health Effects Research Lab US Environmental Protection Agency Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO. 1FA628	
		11. CONTRACT/GRANT NO.	
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development (RTP,NC) Health Effects Research Lab US Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED	
		14. SPONSORING AGENCY CODE EPA-600/11	
15. SUPPLEMENTARY NOTES Published In: Bioelectromagnetics 1, 65-76, 1980			
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17. KEY WORDS AND DOCUMENT ANALYSIS			
a. DESCRIPTORS continuous wave(CW) mutagenesis reproduction rats 2,450 MHz microwaves	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group 06R	
PRODUCT OF: NATIONAL TECHNICAL INFORMATION SERVICE U.S. DEPARTMENT OF COMMERCE SPRINGFIELD, VA. 22161			
18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES	
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE	

Tests of Mutagenesis and Reproduction in Male Rats Exposed to 2,450-MHz (CW) Microwaves

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Tests of mutagenesis and reproduction were conducted in male rats which were irradiated by 2,450-MHz, continuous-wave (CW) microwaves, 4 hr/day from day 6 of gestation to 90 days of age at 5 mW/cm²; or 5 hr/day for five days beginning on the 90th day of age at 10 mW/cm²; or 4 hr/day, 5 days/wk for four weeks, beginning on the 90th day of age. During selected weekly periods after treatment, the rats were bred to pairs of untreated, normal female rats that were examined in late pregnancy by means of the dominant lethal assay. The reproductive efficiency of these males, as reflected in their breeding, was also examined for changes relating to their microwave experience. No significant evidence of germ-cell mutagenesis was detected when data of microwave-exposed males were compared with those of sham-exposed males, even though there were significant increases in rectal and intra-testicular temperatures at a power density of 28 mW/cm². Temporary sterility, as indexed by fewer pregnancies, was seen at the highest power density.

Key words: mutagenesis, reproduction, rats, 2,450 MHz, microwaves, continuous wave (CW)

INTRODUCTION

The possibility that microwave exposure alters male germ cells has been considered by several investigators. Imig et al [1948] demonstrated that the male-rat germinal epithelium is susceptible to damage from microwaves. Furthermore, it has been demonstrated that microwave exposure caused damage to testes at lower testicular temperatures than did infrared heating. Fahim et al [1975] compared microwaves to more conventional methods of testicular heating and suggested the use of diathermy as a male contraceptive. Others have examined men occupationally exposed to microwaves in an effort to evaluate the potential hazards of that exposure; Barron and Baraff [1958] could not observe change in male reproductive capacity, while others [Lancrajan et al, 1975] have reported only a statistical degradation in semen sperm characteristics. More recently, interest has been

Received for review June 7, 1979; revision received December 26, 1979.

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directed to the possibility that microwaves might be a germ-cell mutagen [Varma et al, 1977; Varma and Traboulay, 1977], but these results are inconclusive. A complete evaluation of the public health aspects of electromagnetic radiation should include examination of the possible effects on the male reproductive system. We report an attempt to address these questions with a series of experiments designed to examine the mutagenic potential of electromagnetic radiation in germ cells of male rats.

MATERIALS AND METHODS

Male Sprague-Dawley (CD strain, Charles River Breeding Labs, Inc., Portage, Michigan) rats were used in the three experiments reported here. They either entered into a treatment schedule (Table 1) as fetuses and were continued through 90 days of post-partum age (experiment 1), or were first irradiated as young adults (experiments 2 and 3). On the third day after the treatments ended, each male was housed for one week of breeding with a pair of virgin, 90-day-old females. The development of mature sperm in rats takes approximately 70 days. In the dominant lethal assay, pregnancies resulted from the weekly mating period permit evaluation of sperm exposed in the test agent at various stages of spermatogenesis. For example, matings that occur immediately after exposure to microwave radiation evaluate mature epididymal sperm; matings which occur 50 to 70 days after exposure involve sperm that were in the mitotic phases of spermatogenesis during the exposure. These week-long periods of breeding, and the stages of spermatogenesis treated previously and each breeding are shown in Figure 1. On the tenth day after completion of the breeding period, the females were killed and examined for pregnancy, number of live and dead conceptuses, and enumeration of *corpora lutea* of the pregnancy. Pre-implantation loss was calculated by subtracting the total number of conceptuses (live + dead + resorbed) in the litter from the number of *corpora lutea* of that pregnancy. This loss, if statistically greater in the treated group, may represent the embryonic death due to mutagenic alteration of treated sperm. In experiments 2 and 3, the males were permitted to breed for one week before experimental treatment to assess their reproductive performance. Data were not included for males who had not sired at least one normal pregnancy with at least one fetus during this pretreatment or the first post-treatment

TABLE 1. Irradiation Conditions*

Experiment	No. 1	No. 2	No. 3
Power density (mW/cm ²)	5	10	28
Exposure schedule	4 hr/day; day 6 gesta- tion through 90 days of age	5 hr/day, for 5 days; young adults	4hr/day; 5 days/wk, for 4 wk; young adults
No. of Males			
Sham-irradiated	12	16	6
Irradiated	12	14	6

*All exposures occurred at 2,450-MHz (CW) microwaves.

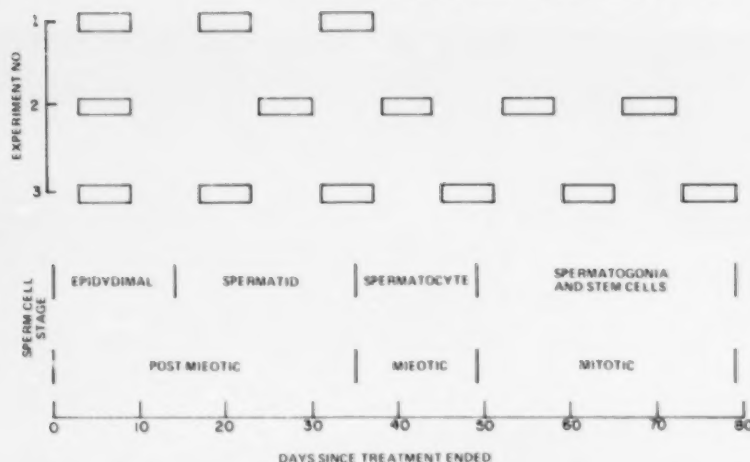


Fig. 1. Weekly breeding schedules, Experiments 1-3 and the treated stage of spermatogenesis represented by each breeding.

period of breeding. On this basis, the data of two males of the irradiated group in experiment 2 were excluded from the study.

Irradiations were conducted in a 2,450-MHz, continuous-wave (CW) microwave facility in which temperature, humidity, and air flow were controlled [Blackman et al 1975; Elder and Ali, 1975]. In experiment 1, there were 12 males in each sham-irradiated or irradiated group. Environmental air was maintained at $50 \pm 5\%$ relative humidity, and a temperature of $26.7 \pm 0.2^\circ\text{C}$ during the first 14 days after birth and $22 \pm 0.2^\circ\text{C}$ thereafter to 90 days of age. A more detailed description of treatment conditions has been reported elsewhere [Smialowicz et al, 1977]. This report includes data on specific absorption rates (SAR) as determined by twin-well calorimetry. The average SARs ranged from 4.7 W/kg at one to five days of age to 0.9 W/kg at 31 to 40 days of age (110–200 g body weight). The male rats used in experiment 1 were the 90-day-old survivors described by Smialowicz [1977] and rats irradiated during 40 to 90 days of age are expected to have SARs somewhat lower than 0.9 W/kg. Experiments 2 and 3 were conducted at $20.2 \pm 0.5^\circ\text{C}$ and 50% relative humidity. In experiment 2, the animals were in slatted Plexiglass © containers (Fig. 2) 8 cm high, 10 cm wide, and 17.5 cm long; eight such containers were arranged so that the long axes of the containers, and the animals in them, were parallel to the H-field vector. Using this arrangement, two sets of eight rats each in the sham-irradiated and irradiated groups were treated. Of 16 irradiated males, two did not qualify by breeding performance as described above and were not included in the analysis. In experiment 3, irradiated male rats were irradiated at a power density of 28 mW/cm² in cylindrical plexiglass containers 17.1 cm long and 8.3 cm in diameter, the top halves of which were drilled with numerous 0.6-cm holes for ventilation. Six such containers were arranged with the long dimension parallel to the E-field vector. Power densities were determined in all experiments using an E-field dipole probe placed at the plane in which the animals would be irradiated [Elder and Ali, 1975], but without

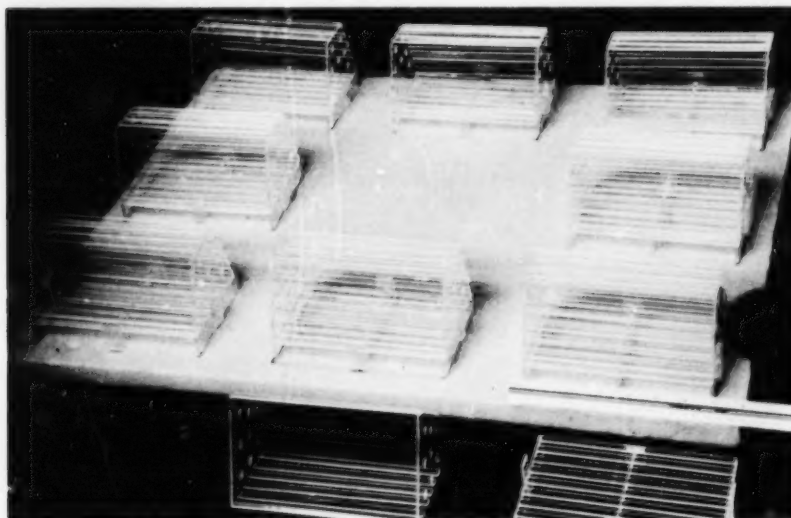


Fig. 2. The "slatted" container in the configuration used in experiment 2. One additional container is shown separated in the foreground. The ruler reads in inches and is oriented parallel to the H-vector.

the presence of cages or animals. SARs were not determined for experiments 2 and 3. However, from Figure 34 in the "Radiofrequency Radiation Dosimetry Handbook" [Durney et al, 1978], we estimate that the SARs are approximately 2.0 mW/g in experiment 2, and 5.6 mW/g in experiment 3. During the intervals between exposures and during breeding periods, males were housed individually in shoe-box-type plastic cages with pine-shaving bedding; food and water were available ad libitum.

Calibrated thermocouples were used to monitor rectal and intratesticular temperatures of mature rats during exposure to microwaves. Prior to exposure, the rats had been injected subcutaneously with 2.5 mg of the narcotic, anileridine. Thermocouples were left in position and readings were made at intervals during 90 minutes of either continuous wave (CW) 2,450-MHz irradiation at 28 mW/cm², or sham irradiation. During this exposure the animal was in the slatted container (Fig. 2). The 90-minute duration of these observations was limited by the effective time of the narcotic.

The males in experiments 2 and 3 were killed by suffocation with CO₂ during the week after the last breeding period. Body and organ weights were determined. Both caudal epididymes were removed from each rat in experiment 2, placed in 2 ml of warmed saline, and cut into small pieces with scissors to allow the sperm to be freed from the lumina. After further dilutions with 10% neutral formalin, the relative sperm concentration in each rat sample was determined with a particle counter (Coulter Counter, Model ZB1, Coulter Electronics, Hialeah, Florida). The percentage of live sperm was determined from smears of the initial, unfixed dilution in the procedure above. Sperm were fixed and stained with eosin-nigrosin. Two hundred cells were examined and the number of live cells was determined [Hackett and Macpherson, 1965].

Only data within a given breeding period and experiment were compared. Pregnancy ratios for each breeding were analyzed by the chi-square statistic. Litter values were used in the analyses of numbers of live and dead conceptuses and post-implantation losses. The fetal data of experiment 2 were first subjected to the Freeman-Tukey transformation, with the number of *corpora lutea* as the denominator, then a multivariate analysis of variance was used to test differences between sham-irradiated and irradiated groups mean responses. Body and organ weights, sperm concentration, and temperatures were also analyzed by analysis of variance.

RESULTS

Tables 2-4 contain the results of the three experiments for each period of breeding following cessation of treatment. Values are given for females in sham-irradiated and irradiated groups. The treatment of experiment 1 resulted in a significant ($P = 0.03$) increase in the number of post-implantation deaths in the sham-irradiated group, but only for the first breeding (Table 2). In this experiment, sham-irradiated rats consistently had more post-implantation losses at each breeding; this trend affected the totals, where values associated with sham-irradiation were significantly high ($P = 0.01$). Other variables were not altered significantly.

There were no significant differences between sham-irradiated and irradiated groups in experiment 2 (Table 3). Data of experiment 1 (and other similar studies conducted in this laboratory, but not reported here) lead us to expect a mean pre-implantation loss of five to ten rats per litter. Throughout experiment 2, the means of pre-implantation losses were unusually low without concomitant increases in the means of total conceptuses. This implies that, for this group of females, there was an unusually low and consistent decrease in the number of *corpora lutea*. Although all females were obtained from the same breeding facility, minor variations in husbandry or breeding practices (seasonal effect) may account for this deviation. The breedings of each experiment were done within a six- to ten-week period. However, approximately three years were taken to complete all the experiments; such a long period can render subjects susceptible to "seasonal" variations. Because we have not attempted any comparisons between experiments, we have retained the *corpora lutea* values and subsequent calculated values, and present them as experimental data.

In experiment 3, pregnancies for the first breeding were severely reduced ($P = 0.03$) in the dams bred with the irradiated group (Table 4). Statistically significant reductions in the number of live fetuses ($P = 0.01$) and in the number of implanted conceptuses ($P = 0.004$) were seen only in dams bred with the irradiated group during the second breeding period. Overall totals showed a significant difference ($P < 0.01$) only in the total number of conceptuses in the litter.

Body and organ weights, and sperm concentrations obtained from the male rats exposed to 2,450-MHz radiation (experiments 2 and 3) are presented in Table 5. No significant differences were found between sham-irradiated and irradiated groups for any of these variables.

Rectal temperatures of narcotized rats rose to an average of 41°C after 60 minutes of exposure to 2,450-MHz radiation at a power density of 28 mW/cm^2 . This represents a mean increase of 4.5°C over that of sham-irradiated rats. The temperature of the testicles also increased under irradiated rats and reached a mean of 37.5°C .

TABLE 2. Results of Matings of Male Rats at Specified Periods After Sham-Irradiation (SHAM) or Irradiation (IRR)* (Experiment No. 1)†

Variable	Breeding, No. of days, since treatment							
	3-9		17-23		31-37		Total	
	SHAM	IRR	SHAM	IRR	SHAM	IRR	SHAM	IRR
Bred females	23	24	23	24	24	24	70	72
Pregnant	20	22	21	23	23	21	64	66
%	87	92	91	96	96	88	91	92
Live/Litter	11.8 ± 3.8	12.5 ± 2.5	12.8 ± 3.3	12.7 ± 2.8	13.3 ± 2.5	13.1 ± 2.8	12.6 ± 3.2	12.8 ± 2.7
Dead/Litter	2.2 ^a ± 3.2	0.6 ± 0.7	1.3 ± 2.5	0.8 ± 0.9	1.7 ± 2.1	1.2 ± 1.0	1.7 ^b ± 2.6	0.9 ± 0.9
Total/Litter	13.9 ± 2.0	13.1 ± 2.3	14.1 ± 1.5	13.6 ± 3.0	15.0 ± 1.9	14.4 ± 2.5	14.2 ± 2.2	13.7 ± 2.7
Pre-implantation Loss/litter	9.3 ± 3.6	7.8 ± 4.8	6.2 ± 3.6	7.0 ± 4.9	8.0 ± 4.2	9.7 ± 6.3	7.8 ± 4.0	8.1 ± 5.4

*Irradiation was 5 mW/cm², 2,450-MHz (CW) microwaves 4hr/day beginning on day 6 in utero through 90 days of age

†Values for litters are means ± SD

^ap=0.03^bp=0.01

TABLE 3. Results of Matings of Male Rats at Specified Periods After Sham-Irradiation (SHAM) or Irradiation (IRR)[†] (Experiment No. 2)*

Variable	Breeding, No. of days since treatment					
	3-9		24-30		38-44	
	SHAM	IRR	SHAM	IRR	SHAM	IRR
Bred Dams	32	26	32	28	32	28
Pregnant dams	30	26	32	26	31	26
%Pregnant	94	100	100	93	97	93
Live/litter	12.8 ± 1.8	13.3 ± 2.4	13.6 ± 1.8	12.7 ± 2.0	13.4 ± 2.8	12.5 ± 2.6
Dead/litter	0.6 ± 0.6	0.5 ± 0.7	0.3 ± 0.6	0.8 ± 1.1	0.6 ± 1.2	0.5 ± 0.6
Total/litter	13.5 ± 1.9	14.9 ± 1.9	13.9 ± 1.5	15.7 ± 3.4	14.0 ± 2.4	14.8 ± 3.1
Pre-implantation loss/litter	2.0 ± 2.5	1.1 ± 1.4	1.6 ± 1.8	2.2 ± 2.5	2.3 ± 2.6	1.8 ± 2.2
Total						
Variable	52-58		66-72		Total	
	SHAM	IRR	SHAM	IRR	SHAM	IRR
	SHAM	IRR	SHAM	IRR	SHAM	IRR
Bred Dams	31	28	32	27	159	137
Pregnant dams	29	24	29	23	151	125
%Pregnant	94	86	91	85	95	91
Live litter	13.7 ± 3.0	13.1 ± 2.8	12.1 ± 2.7	13.7 ± 1.7	13.1 ± 2.5	13.1 ± 2.3
Dead/litter	0.7 ± 0.9	0.5 ± 0.7	0.5 ± 0.7	0.8 ± 1.0	0.5 ± 0.9	0.6 ± 0.9
Total/litter	14.3 ± 3.0	13.7 ± 2.7	12.6 ± 2.7	14.5 ± 1.5	13.7 ± 2.4	13.7 ± 2.3
Preimplantation loss/litter	2.9 ± 4.3	3.7 ± 4.3	3.8 ± 3.3	2.1 ± 3.1	2.5 ± 3.1	2.2 ± 2.9

[†]Values for litters are means ± SD.*10 mW/cm², 2,450-MHz (cw) microwaves 5 hr/day for five days.

TABLE 4. Results of Matings of Male Rats at Specified Periods after Sham-irradiation (SHAM) or Irradiation (IRR) (Experiment No. 3)*

Variable	Breeding. No. of days, following treatment					
	3-9		17-23		31-37	
	SHAM	IRR	SHAM	IRR	SHAM	IRR
Bred females	12	12	12	12	11	12
Pregnant	11 ^a	6	11	12	10	9
%	92	50	92	100	91	75
Live/litter	12.9 ± 2.8	14.7 ± 2.3	15.2 ^b ± 2.5	11.3 ± 3.9	14.4 ± 4.4	13.4 ± 2.1
Dead/litter	0.9 ± 1.2	0.8 ± 1.0	1.0 ± 1.3	0.3 ± 1.7	0.8 ± 1.2	0.8 ± 0.8
Total/litter	13.8 ± 2.6	15.5 ± 2.7	16.2 ^c ± 2.4	11.7 ± 3.9	15.2 ± 3.4	14.2 ± 2.3
Totals						
	45-51		59-65		72-78	
	SHAM	IRR	SHAM	IRR	SHAM	IRR
Bred females	12	12	12	12	12	12
Pregnant	10	11	11	10	10	11
%	83	92	92	83	83	92
Live/litter	13.8 ± 1.2	14.1 ± 1.3	14.0 ± 3.1	11.8 ± 4.4	13.2 ± 3.3	12.4 ± 3.7
Dead/litter	0.6 ± 0.8	0.8 ± 1.0	0.3 ± 0.5	0.3 ± 0.7	0.7 ± 0.7	0.7 ± 1.2
Total/litter	14.4 ± 1.4	14.9 ± 1.2	14.3 ± 3.0	12.1 ± 4.5	13.9 ± 2.9	13.1 ± 3.8
Totals						
					71	72
					63	59
					89	82
					13.8 ± 3.4	12.8 ± 3.3
					0.7 ± 1.0	0.6 ± 1.0
					14.6 ^d ± 2.7	13.2 ± 3.5

*p = 0.03;

*28 mW/cm², 2.450-MHz microwaves 4 hr/day, 5 days/wk for four weeks;

ap = 0.03

bp = 0.01

cp = 0.04

dp < 0.01

TABLE 5. Body and Organ Weights and Sperm Concentrations in Male Rats Sham-Irradiated (SHAM) or Irradiated (IRR) With 2,450-mHz (CW) Microwaves (Experiments No. 2 and No. 3)*

Variable	Experiment No. 2 ^a		Experiment No. 3 ^b	
	SHAM	IRR	SHAM	IRR
No. of males	16	14	6	6
Body weight (g)	524 ± 25	526 ± 34	667 ± 33	661 ± 108
Testes weight (g)	3.67 ± 0.36	3.89 ± 0.41	4.18 ± 0.30	4.12 ± 0.18
Liver weight (g)	—	—	29.1 ± 3.9	30.2 ± 2.7
Adrenal weight (mg)	—	—	26 ± 2	25 ± 5
Relative concentration of epididymal sperm (%) Live sperm	7119 ± 1283	7067 ± 1510	—	—

*Values are means ± SD, except for No. of males.

^a10 mW/cm², 5 hr/day for five days;

^b28 mW/cm² 4 hr/day, 5 days/wk for four weeks.

DISCUSSION

Ray and Hyneck [1973] have characterized a true mutagenic response in the dominant lethal assay. Criteria require that there be a consistent pattern of a significant increase of fetal death in litters coupled with a decrease of live fetuses in litters, and that (when a dose-response experimental design is employed) these two fetal alterations occur due to alteration in the same stage of spermatogenesis. The authors suggest that if experimental results do not follow this pattern, one is in danger of interpreting spurious results as mutagenic.

Using the criteria suggested by Ray and Hyneck [1973] to examine the results of our three experiments, we are not lead to the conclusion that the treatments produced a mutagenic response. Although there are significant statistical differences among some variables at some stages of spermatogenesis, the pattern is not consistent and the increase of fetal mortality is not coupled with a decrease of live fetuses.

Other authors have reported a mutagenic effect in mouse germ cells due to 2,450-MHz irradiation [Varma et al, 1977] and to 1,700-MHz irradiation [Varma and Traboulay, 1977]. Reexamination of their data in the light of the same criteria we have employed does not support the authors' conclusion. More specifically, the authors used individual conceptuses in the calculations and in the subsequent statistical analyses of mutagenicity indices. Further review of their tabulated data reveals inconsistencies in the production of increased mutagenicity in weekly breedings. They also ignored the wide variations in the pregnancy rates of the females bred to sham-irradiated animals, and the inference that a low pregnancy rate in sham-irradiated animals may imply an abnormal population. Therefore, it still remains to be demonstrated that microwaves, even at near-lethal doses, can cause a dominant lethal mutagenic effect in the mouse or the rat.

TABLE 6. Means $\pm$ SD of Rectal and Intratesticular Temperatures ($^{\circ}$ C) of Sham-Irradiated Rats and Rats Irradiated at 2,450-MHz After Subcutaneous Injection of 2.5 mg Anileridine

Minutes	mW/cm ²					
	0			28		
	N	Rectal	Testicular	N	Rectal	Testicular
0	3	38.8 $\pm$ 0.2	34.6 $\pm$ 0.4	4	38.4 $\pm$.4	33.9 $\pm$.6
5	3	38.5 $\pm$ 0.3	33.7 $\pm$ 1.1	4	38.8 $\pm$.4	34.9 $\pm$.6
10	3	38.2 $\pm$ 0.4	33.3 $\pm$ 1.2	4	39.1 $\pm$.4	35.8 $\pm$.6
15	3	37.8 $\pm$ 0.5	33.2 $\pm$ 1.2	4	39.4 $\pm$.4	36.3 $\pm$.6
30	3	37.3 $\pm$ 0.6	33.1 $\pm$ 0.9	4	40.1 $\pm$.3	37.0 $\pm$.7
45	3	37.0 $\pm$ 0.7	32.4 $\pm$ 0.1	4	40.5 $\pm$.2	37.2 $\pm$ 1.0
60	3	36.5 $\pm$ 1.0	31.8 $\pm$ 1.1	3	40.8 $\pm$.3	36.8 $\pm$ 1.4
90	3	36.5 $\pm$ 0.8	32.1 $\pm$ 0.8	2	40.9 $\pm$.2	37.5 $\pm$ 1.9

Reproductive efficiency (fertility) was also examined in this study. As in the evaluation of the data of the dominant lethal assay, no consistent functional change in fertility could be seen. Only in the most severe regimen (experiment 3) was there any hint of a deleterious effect. In the breedings that took place from three to nine days after treatment, only 50% of the dams bred to irradiated males showed pregnancies. This effect was temporary, lasting only until the next breeding period, 17 days after treatment. Heat sensitivity in spermatogenesis increases with the age (or stage) of the sperm cell development and the most advanced cells (spermatozoa) are most sensitive [Van Demark and Free, 1970]. The pattern of temporary relative infertility seen in these data is consistent with the concept (and our interpretation) that the conditions in experiment 3 are the minimal needed to cause any significant loss of fertility in male rats. The temperatures reached in the testicle under these experimental conditions approximated resting body temperatures ($\approx 37^{\circ}$ C). See Table 6. These exposure conditions may have created a situation that affected a "pseudocryptorchid" state, resulting in temporary sterility in at least some of the males. There are no data in Table 5 to suggest that the infertility was due to changes in sperm viability, morphology or physiology. However, it has been shown that decreased fertility rates caused by thermal loads are associated with pre-implantation mortality [Burfening et al, 1970]. Results seen in this series of experiments are consistent with this phenomenon: The lack of pregnancies may be interpreted as being due to pre-implantation loss. Our failure to count *corpora lutea* limits our ability to make a more definitive statement about pre-implantation loss.

Most experiments on testicular effects of microwaves in rodents have not used functional fertility to assess radiation effects, but instead have relied upon examination of tissues for histopathologic changes. There are two excellent reviews of research on the effects of microwaves on fertility in the male [Baranski and Czerski, 1976; Carpenter, 1977]. The authors of one study [Prausnitz and Susskind, 1962] reported tubular atrophy in the testes of mice exposed four and one-half minutes daily for 16 months to 9,270-MHz

(pulsed) radiation at a power density of 100 mW/cm^2 . In retrospect, it is surprising that it took so long to evince a pathologic response. It is very interesting to note that all survivors of an LD_{50} experiment reported by these authors eventually proved to be potent.

Much of the interest expressed in microwaves as a source of decreased fertility in the male stems from expectations of its use as a contraceptive. In such studies testicular temperatures at or above body temperature are reached, and usually other sources of heat are compared to microwaves for effectiveness [Muraca et al, 1977; Imig et al, 1948; Fahim et al, 1975]. Another reason for studying the influence of microwaves as an influence on male fertility is to determine if this environmental and occupational agent is a hazard to normal conception. Barron and Baraff [1958] examined 226 men exposed to radio-frequency radiation at radar frequencies for periods up to 13 years. Their criterion for effects on fertility was the incidence of childless marriages; no difference between exposed and control subjects was seen. Neither could they obtain from the radar-exposed male subjects a single admission of sterility. Lancrajan et al [1975] examined a group of 31 men occupationally exposed to microwaves. Their index of fertility was based on the examination of a semen ejaculate. They noted a statistically significant decrease in the number of sperm cells, in the percentage of normal sperm cells, and in sperm motility in 74% of the subjects. Two-thirds of the affected men responded with spermatogenic improvement after a three-month rest from occupational exposure to microwaves.

The male reproductive system is an excellent example of abundance. The concentration of sperm in ejaculates of normal men ranges from 60 to 150 million/ml [Conn, 1971]. It is this natural extravagance that might explain the inability to demonstrate clinical sterility [Barron and Baraff, 1958] when only a slight decrease in potency [Lancrajan et al, 1975] is reported to be caused by microwave exposure. In rats whose epididymal sperm was examined in our study, no deviation of consequence could be seen, nor were there changes in testicular weight.

In conclusion, we were not able to demonstrate a male germ-cell mutagenesis in rats after repetitive or chronic exposures to 2,450-MHz CW radiation, although SARs in these studies ranged to 5.6 W/kg . Furthermore, reexamination of data in reports indicating a microwave-induced dominant lethal effect in mice were shown to be improperly interpreted. Functional reproductive loss, in the form of a temporary sterility in some subjects, may have been demonstrated under conditions ($2,450 \text{ MHz}$, 28 mW/cm^2 , for 5 days/wk for four weeks) in which the testicular temperature was raised appreciably.

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